A model of opinion dynamics based on formal argumentation: application to the diffusion of the vegetarian diet

Patrick Taillandier[1][0000−0003−2939−4827], Nicolas Salliou[2][0000−0003−3960−2175], and Rallou Thomopoulos[3][0000−−0002−3218−9472]

[1] MIAT, University of Toulouse, INRAE, Castanet-Tolosan, France
patrick.taillandier@inra.fr
[2] ETH Zürich, IRL, PLUS, Stefano-Franscini-Platz 5, 8093 Zürich, Suisse
nsalliou@ethz.ch
[3] IATE, Univ. Montpellier, INRAE, Montpellier SupAgro, CIRAD, INRIA GraphIK, 34060 Montpellier, France
rallou.thomopoulos@inra.fr

1 Context

This generic agent-based model simulates the evolution of agents' opinions through their exchange of arguments. The idea behind this model is to explicitly represent the process of mental deliberation of agents from arguments to an opinion, through the use of Dung's argumentation framework complemented by a structured description of arguments. An application of the model on the diffusion of vegetarian diets is proposed.

2 Main concepts

The idea behind this model is to explicitly represents agents' own mental deliberation process from arguments towards an opinion, through the use of the argumentation framework. We use the argumentation framework of [Dung(1995)] (Definition 1) complemented with a structured description of arguments extending those introduced in [Thomopoulos et al.(2018)Thomopoulos, Moulin & Bedoussac] (Definition 2).

Definition 1. ***Dung's argumentation graph.*** *An argumentation graph is a pair $(\mathcal{A}, \mathcal{R})$ where $\mathcal{A}$ is a set of arguments and $\mathcal{R} \subseteq \mathcal{A} \times \mathcal{A}$ is an attack relation. An argument a attacks an argument a' if and only if $(a, a') \in \mathcal{R}$.*

Definition 2. ***Argument.*** *We define an argument by a tuple $a = (I; O; T; S; R; C; A; Ts)$, with:*
I: the identifier of the argument;
O: the option that is concerned by the argument;
T: the type of the argument: pro, con or neutral towards the option;
S: the statement of the argument, i.e. its conclusion;

R: the rationale underlying the argument, i.e. its hypothesis;
C: the importance of each criterion (e.g. "Nutritional", "Economic", "Environmental") on which the argument relies on;
A: the agent who proposes the argument;
Ts: the type of source the argument comes from.

We thus consider that each agent is characterized by a set of attributes:
argumentation graph: a directed graph that represents a Dung's argumentation system. Each node is an argument, and each edge represents an attack from an argument to another one. The weight of an edge represents the strength of the attack for the agent. The interested reader can refer to [Yun et al.(2018)Yun, Thomopoulos, Bisquert & Croitoru] for different ways to define attacks.
criterion importance: for each criterion that arguments rely on, a score (numerical value between 0 and 1) represents the importance of this criterion for the agent. As opinions are formed from a cognitive and an affective part bergman1998theoretical, criterion are used to evaluate the affective preference of arguments.
opinion: a numerical value that corresponds to the opinion of the agent. A value higher than 0 means that the agent is in favour of the option, a value lower than 0 means that the agent is against the option, and if the value is 0, the agent is neutral towards the option.
behavior: a nominal value that corresponds to the behavior resulting from the agent's opinion. Examples of possible values in the food diet application are *omnivorous*, *flexitarian*, *vegetarian* or *vegan*. There is thus a mapping between the opinions, defined on a numerical domain, and the set of behaviors, which label predefined consumer profiles.

We define the notion of strength of an argument for an agent.

Definition 3. ***Argument strength.*** *Let us consider an agent j, the strength of an argument a is defined as follows:*

$$strength(j,a) = \sum_{c \in CRIT} j_c \times a_c \tag{1}$$

with $CRIT$, the set of criteria, a_c the importance of the criterion c for the argument a (see Definition 2), and j_c the importance of c for the agent j.

From the notion of strength, we define the notion of value for a set of arguments.

Definition 4. ***Value of a set of arguments.***

Let us consider a set of arguments A for an agent j, the value of this set of arguments is computed as follows:

$$value(j,A) = \frac{\sum_{a \in A} strength(j,a) \times type(a)}{\sum_{a \in A} strength(j,a)} \tag{2}$$

with: $type(a) = \begin{cases} -1 & \textit{if type of } a = con \\ 0 & \textit{if type of } a = neutral \\ 1 & \textit{if type of } a = pro \end{cases}$

Using the notion of strength, we also define the notion of simplified argument graph:

Definition 5. ***Simplified argumentation graph.*** *Let us consider an agent j, $(\mathcal{A}, \mathcal{R})$ an argumentation graph and $(a, a') \in \mathcal{R}$. The simplified argumentation graph $(\mathcal{A}, \mathcal{R}')$ obtained from $(\mathcal{A}, \mathcal{R})$ is defined by: $(a, a') \in \mathcal{R}'$ if and only if:*
$(a, a') \in \mathcal{R}$ and
if $(a', a) \in \mathcal{R}$ then $strength(j, a) \geq strength(j, a')$.

This means that if an argument a attacks an argument a' and if a' attacks a, only the attack that has for origin the argument with the highest strength is kept in the simplified graph. If the arguments have the same strength, both attacks are kept.

Finally, we define the notion of preferred extension.

Definition 6. ***Preferred extension.*** *Let an argumentation system $(\mathcal{A}, \mathcal{R})$ and $B \subseteq \mathcal{A}$. Then:*
B is conflict-free if and only if $\nexists a_i, a_j \in B$ such that $(a_i, a_j) \in \mathcal{R}$;
B defends an argument $a_i \in B$ if and only if for each argument $a_j \in \mathcal{A}$, if $(a_j, a_i) \in \mathcal{R}$, then $\exists a_k \in B$ such that $(a_k, a_j) \in \mathcal{R}$;
a conflict-free set B of arguments is admissible if and only if B defends all its elements. A preferred extension is a maximal (with respect to set inclusion) admissible set of arguments.

2.1 Dynamics

We made the choice to use the same general model as the one proposed in mas2013differentiation. A simulation step corresponds to the exchange of an argument between two agents, i.e. an agent gives one of his/her arguments to another agent. When an agent learns a new argument, the oldest argument is removed from his/her argumentation graph. This forgetting process, already defined in mas2013differentiation, was introduced to take into account the limitation of human cognition and memory. We also integrated the the use of an argument, i.e. giving it to another agent, triggers the agent to remember it. The given argument is automatically considered as the agent's most recent argument. Similarly, an agent who receives an argument he/she already has will not add it again in his/her argumentation graph, but will consider this argument as the most recent among his/her arguments. The effect of this mechanism is that some arguments may be forgotten by the entire population of agents. Thus, for example, if all agents tend to converge towards the same opinion, most of the arguments against that opinion will be forgotten.

Concerning the choice of the agent to exchange arguments with, we used the same partner selection method as mas2013differentiation. In each simulation step, an agent chosen randomly (uniform distribution) selects another agent. The probability that the second agent is chosen as an interaction partner depends on the similarity between the two agents in terms of opinion.

Let i and j be 2 agents, the similarity between i and j is:

$$Similarity(i,j) = \frac{1}{2}(2 - |i.opinion - j.opinion|) \quad (3)$$

And the probability for an agent i to select j for partner considering N the set of all possible partners is:

$$Proba_i(j) = \frac{(Similarity(i,j))^h}{\sum\limits_{k \in N}(Similarity(i,k))^h} \quad (4)$$

With h, the strength of homophily.

For the choice of the argument to be given, our hypothesis is that an agent will give an argument that seems relevant to him/her and that allowed him/her to form his/her opinion. In other words, it means picking an argument belonging to the set of arguments in the preferred extension maximizing the absolute value of opinion as defined in Equation 2. The agent will choose a random argument in this set.Our proposal to randomly choose which argument to give to another agent is due to the dependence of such action on external factors not represented in the model such as the course of the discussion between individuals, the profile of the other, etc. Other choices could have been made such as giving the argument with the highest strength, the argument with the highest chance of convincing the other, etc. We discuss this point in the perspectives of the article.

Note that in the case of an argumentation graph without attacks, there will be only one preferred extension which will be composed of all the arguments considered by the agent. We thus find ourselves in the same case as the ACTB model where the agent chooses an argument at random among all the arguments at his/her disposal. In the other cases, the ranking between several co-existing preferred extensions is known as the “ranking semantics” problem yun2020. We made a modeling choice stating that an agent chooses the preferred extension with the highest value, which expresses the motivation to favor the most adamant view stemming from the extensions.

Once an agent receive a new argument (and at the initialization of the model), the agent deliberates using his/her argument graph to make his/her opinion. Contrary to mercier2011humans who state that individuals will be strongly critical of any new argument challenging their own opinion, we assumed no such psychological reactance brehm1966theory. The deliberation is composed of 3 steps:
simplifying the argumentation graph according to the weights of the edges (see Section 5);
computing the set of preferred extensions from the simplified argumentation graph (see Section 6);
computing the opinion from the preferred extensions: for each extension, the agent computes its value using Equation 2, then returns the extension with the maximal absolute value. If several extensions have the same absolute value, then the agent randomly selects one of these extensions.

If we consider an argumentation graph with no attack and that all the criteria have the same importance for all the agents, then, we are in the exact context of the ACTB model, when all relevant arguments have the same persuasiveness (i.e. all arguments are equally weighted in the calculation of the opinion). In this case, the evaluation of an opinion of an agent j with a set of arguments A can be directly computed by:

$$opinion(j) = \frac{\sum\limits_{a \in A} type(a)}{Card(A)} \tag{5}$$

with: $type(a) = \begin{cases} -1 & \text{if type of a = con} \\ 0 & \text{if type of a = neutral} \\ 1 & \text{if type of a = pro} \end{cases}$

Convergence towards a steady state can only be achieved if none of the agents can change their opinion no matter what happens in terms of exchanging arguments. The definition of such a steady state depends on the strength of homophily h. Indeed, the model relies on a stochastic choice of agents to exchange arguments (see 4): if $h = 0$, it means that all agents can exchange arguments with all other agents even if they have a very different opinion; if $h > 0$, it means that all the agents can exchange arguments with all other agents unless they have a completely different opinion (i.e. if one of the agents has a -1 opinion and the other has a 1 opinion). Thus, in the first case, to be sure to obtain a stable state, all the agents must have the same opinion (-1 or 1) and arguments of a homogeneous type (all pro or all con). In the case of $h > 1$, the first condition can be relaxed: all agents must have arguments of homogeneous type (all pro or all con) but their opinion can be either -1 or 1. Indeed, in this case, the agents will only exchange arguments with agents who already have the same opinion as them and the new arguments brought, in accordance with the opinion of both agents, will not have an impact on the result of the opinion calculation.

3 Implementation

The model was implemented with the GAMA platform taillandier2019building. GAMA provides modelers with a dedicated modeling language which is easy to use and learn. It also allows them to naturally integrate GIS data and includes an extension dedicated to generating a spatialized and structured synthetic population chapuisGenstar, which is particularly interesting for building empirically grounded models. The main components of the model (arguments, argumentative agents, etc.) were implemented as a plugin for the GAMA platform. The interest of making a plug-in is to facilitate the reuse of these elements in other models. Thus, a modeler wishing to use them will just have to import the plugin and she/he will be able to directly use all these functions. This is particularly interesting for non simple functions such as the calculation of preferred extensions which is based on the JArgSemSAT Java library cerutti2017. The plugin was designed to be as modular as possible allowing the modelers to customize all the existing functions (for example, the computation of the argument strength). It was developed under the GPL-3 licence, and is available on Github[4]. It can be directly downloaded and installed from GAMA 1.8.1 from the GAMA experimental p2 update site[5].

Acknowledgment

This work is part of the VITAMIN ("VegetarIan Transition Argument ModellINg") project funded by INRAE.

References

Dung(1995). Dung, P. M. (1995). On the acceptability of arguments and its fundamental role in nonmonotonic reasoning, logic programming and n-person games. *Artificial Intelligence Journal*, *77*, 321–357

Thomopoulos et al.(2018)Thomopoulos, Moulin & Bedoussac. Thomopoulos, R., Moulin, B. & Bedoussac, L. (2018). Supporting decision for environment-friendly practices in the agri-food sector: When argumentation and system dynamics simulation complete each other. *International Journal of Agricultural and Environmental Information Systems*, *9*(3), 1–21

Yun et al.(2018)Yun, Thomopoulos, Bisquert & Croitoru. Yun, B., Thomopoulos, R., Bisquert, P. & Croitoru, M. (2018). Defining argumentation attacks in practice: An experiment in food packaging consumer expectations. In P. Chapman, D. Endres & N. Pernelle (Eds.), *Graph-Based Representation and Reasoning*, (pp. 73–87). Cham: Springer International Publishing

[4] https://github.com/gama-platform/gama.experimental

[5] http://updates.gama-platform.org/experimental